PATENT SPECIFICATION

1,062,269

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COMPLETE SPECIFICATION

DRAWINGS ATTACHED

Improvements in or relating to Band-Pass Filters

We, COMPAGNIE FRANCAISE THOMSON-HOUSTON-HOTCHKISS BRANDT, formerly COMPAGNIE FRANCAISE THOMSON-HOUSTON, a French Body Corporate, of 173 Boulevard Haussmann, Paris VIII, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to band-pass filter with a linear phase characteristic of a new type which has both steep edges and a constant propagation time. In fact these two properties seem incompatible and it is known that circuits obeying the law of minimum phase shift and having a rapid variation of their law of amplitude also have a rapid variation of their phase law.

An object of the present invention is a filter which possesses, to a degree greater than has hitherto been possible, these two properties at the same time: steep edges and a constant propagation time and which is especially important in its application in the field of pulse compression. This is because in the field of pulse compression, apart from obvious desirability of having phase shift characteristics approaching linearity, it is necessary that a pulse feeding a dispersive network, be as "clean" as possible, that is that the pulse should approximate as nearly as possible the ideal and rectangular shape. Under such ideal conditions no distortion occurs when compression is carried out.

The invention consists in a band pass filter exhibiting a steep edge amplitude-frequency response characteristic and a phase characteristic at least approaching linearity, wherein there is provided a plurality of channels in parallel connection, each channel consisting of a series resonant circuit and a phase shifting network, the tuning frequencies of said resonant circuits being in uniformly staggered relationship and each phase shifting network adding respectively, to the intrinsic phase shift of the resonant circuit to which it is series connected, a supplemental phase shift differing by $\pi/2$ from that of the preceding phase shift network whereby the total phase angle of any one channel differs by $\pi/2$ from that preceding it.

In order that the invention may be more clearly understood, reference will now be made to the accompanying drawings which show one embodiment thereof by way of example, and in which:

Figure 1 is a diagrammatic representation of a filter according to the invention,

Figure 2 a response curve of the filter of Figure 1,

Figure 3 the phase curve of a filter according to the invention.

As referred to above, it is difficult to construct a band-pass filter, the amplitude response curve of which has steep edges and the total phase shift of which in the band is linear. It is known that these two properties are generally incompatible in minimum phase shift filters.

The invention enables this disadvantage to be avoided by producing a filter which, while it does not obey the minimum phase shift law has both steeper edges and a more nearly linear phase characteristic than has hitherto been posisble at the same time.

Figure 1 is a diagrammatic representation of an embodiment of a filter according to the invention.

The signals appearing at the input 1 are applied to a distribution circuit 2 which applies them in parallel to a plurality of channels each comprising a series resonant circuit 3_1, 3_2 . . . 3_p . . . 3_n. These resonant

circuits have tuning frequencies which are staggered in relation to each other and selected in such a way that the pass bands of two adjacent resonant circuits intersect at $3db$ intervals. If B is the total pass band of the filter, the pass band of each individual resonant circuit is b which is very close to B/n so that the centre frequency of any circuit i is selected to be equal to: $Fi = Fo - B/2 + B/n\ (i - \frac{1}{2})$, i obviously varying from 1 to n, and Fo being the central frequency of the filter.

Each channel comprises in series the resonant circuits 3_1 to 3_n, phase-shift circuits 4_1 to 4_n which adds in each channel a supplemental phase shift of $\pi/2$ in relation to the phase shift of the preceding channel, said circuits 4_1 to 4_n having phase shift values passing from zero to $(n\text{-}1)\ \pi/2$, for integral values of $\pi/2$ successively from one to another. A summation circuit 5 then effects the vectorial sum of the signals appearing respectively in parallel at the outlet of the channels of the filter. The resulting signal is taken off at 6.

Figure 2 gives the amplitude response curve 7 of the filter as a function of frequency with the resonant curves of the different circuits with staggered tuning which constitute it.

Each circuit with staggered tuning constituting the filter has, in relation to the preceding circuit, a supplemental phase shift independent of frequency and equal to $\pi/2$.

In this manner it can be established that if the phase shift of the first resonant circuit is taken as a reference, the p th. circuit has a phase shift $\Delta\phi p = (p - 1)\ \pi/2 = (j - 1)\ \pi/2$ when $p = 4k + j$ since whole multiples of 2π may be disregarded.

The number of circuits used which gives the steepest edges is an integral multiple of 4. In fact for a signal with a frequency outside the total band of the filter, i.e. separated from the tuning frequencies of all the resonant circuits, the responses of all the resonant circuits are weak and of the same order of size. The additional phase shifts $(p - 1)\ \pi/2$ cause the vector sum of these responses to give a very small amplitude result (less than the response of an isolated circuit).

On the other hand for a signal with a frequency within the total band of the filter, the response of the assembly is approximately dominated by the response of the next-adjacent resonant circuits. This results in the amplitude response curve 7 of the total filter (Figure 2).

Figure 3 shows the resulting phase shift curve 9 of the filter according to the invention as a function of the frequency.

For a given frequency the phase of the total filter is approximately imposed by the phase of the resonant circuit or circuits next adjacent to this frequency. The phase shift curves of the different resonant circuits constituting the filter are seen at 8_1, 8_2, 8_n in Figure 3. However the positions which they take up in relation to each other are due to the phase shifters 4_1, 4_n which are adjacent to the resonant circuits $3_1 - 3_n$ and which add a supplemental phase shift of $\pi/2$ to a circuit in relation to the previous one. It can been seen from the Figure that in these conditions the curve representing the total phase shift of the filter according to the invention varies in a linear manner.

A band-pass filter with linear phase characteristic has thus been described, which filter is, among other uses, more particularly useful in the field of pulse compression and which has an amplitude response curve with steep edges and a low residual ripple. It will be apparent that any desired number of staggered tuning circuits or circuits introducing a supplemental phase shift may be used.

WHAT WE CLAIM IS:—

1. Band pass filter exhibiting a steep edge amplitude-frequency response characteristic and a phase characteristic at least approaching linearity, wherein there is provided a plurality of channels in parallel connection, each channel consisting of a series resonant circuit and a phase shifting network, the tuning frequencies of said resonant circuits being in uniformly staggered relationship and each phase shifting network adding respectively, to the intrinsic phase shift of the resonant circuit to which it is series connected, a supplemental phase shift differing by $\pi/2$ from that of the preceding phase shift network whereby the total phase angle of any one channel differs by $\pi/2$ from that preceding it.

2. Band pass filter according to claim 1 wherein there is provided a distribution circuit fed with the incoming signals and feeding a plurality of parallel channels comprising each a series resonant circuit tuned on a given frequency and having a band pass which is a fraction of the total band pass of the filter, a phase shifter being series connected with each said resonant circuit and adding, to the intrinsic phase shift thereof, a supplemental phase angle which is either zero of an integral multiple of $\pi/2$, said phase shifter being so arranged that this phase shift varies further more by increasing values of $\pi/2$ from one channel to another whereby the p^{th} channel has a phase shift of $(p\text{-}1)\ \pi/2$, a summation network being provided for the vectorial summation of the output signals of the said parallel channels.

3. Band pass filter according to the preceding claims wherein the number of the contemplated channels is an integral mul-

tiple of 4.

4. Band pass filter substantially as hereinbefore described with reference to the accompanying drawings.

BARON & WARREN,
16, Kensington Square,
London, W.8.
Chartered Patent Agents.

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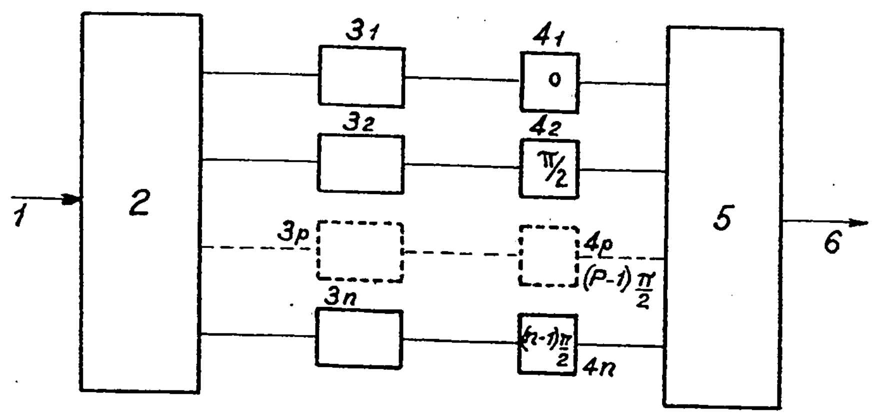

Fig. 1

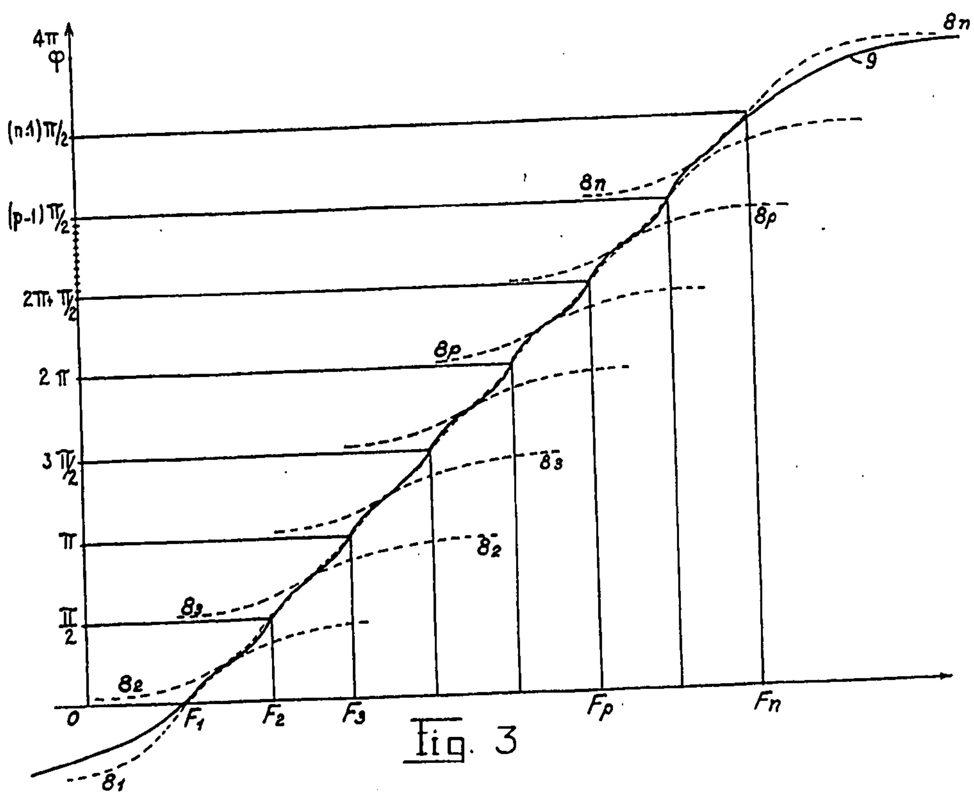
4π
φ
(n-1)π/2
(p-1)π/2
2π+π/2
2π
3π/2
π
π/2
0
F1
F2
F3
Fp
Fn
8n
9
8p
8n
8p
83
82
83
82
81

Fig. 3

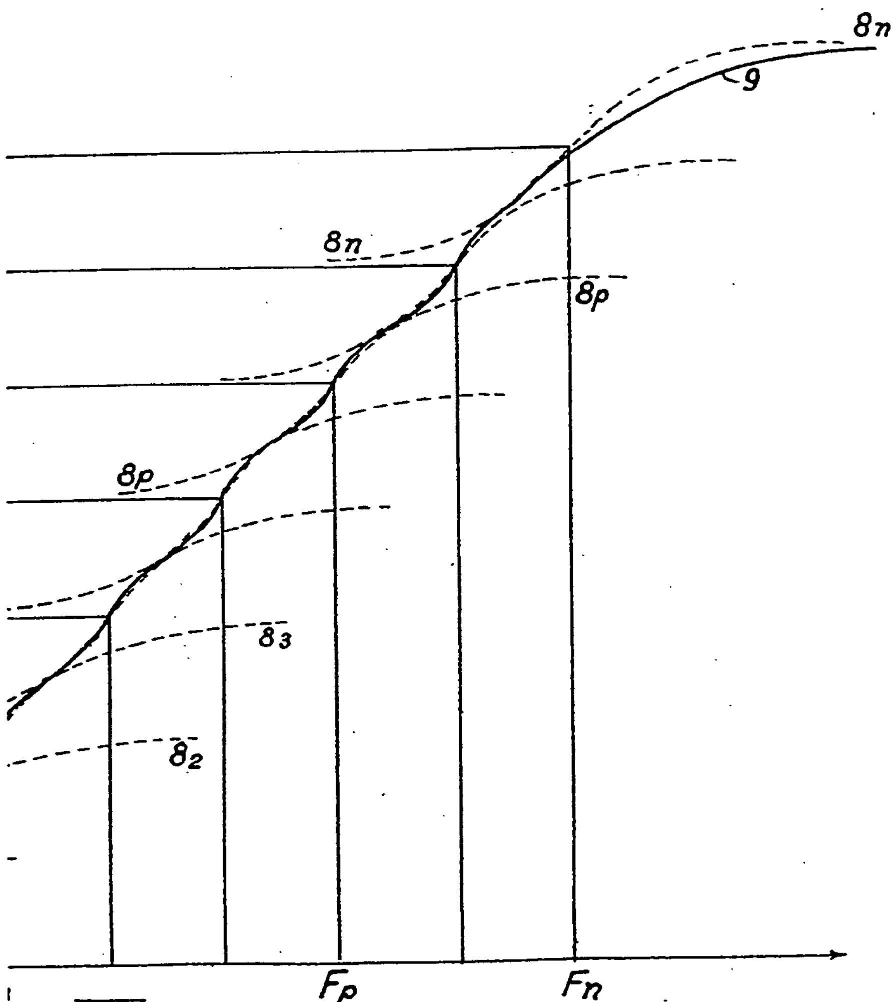

Fig. 3

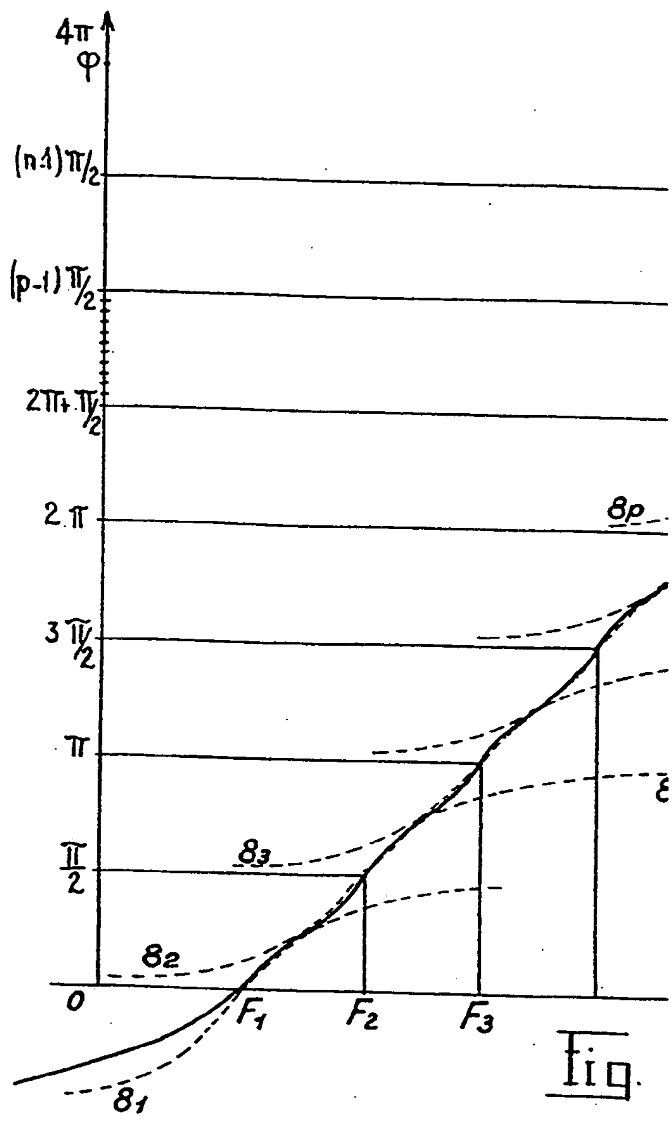

Fig.

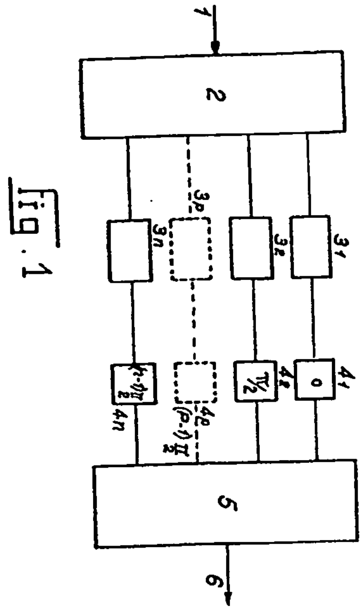

Fig. 1

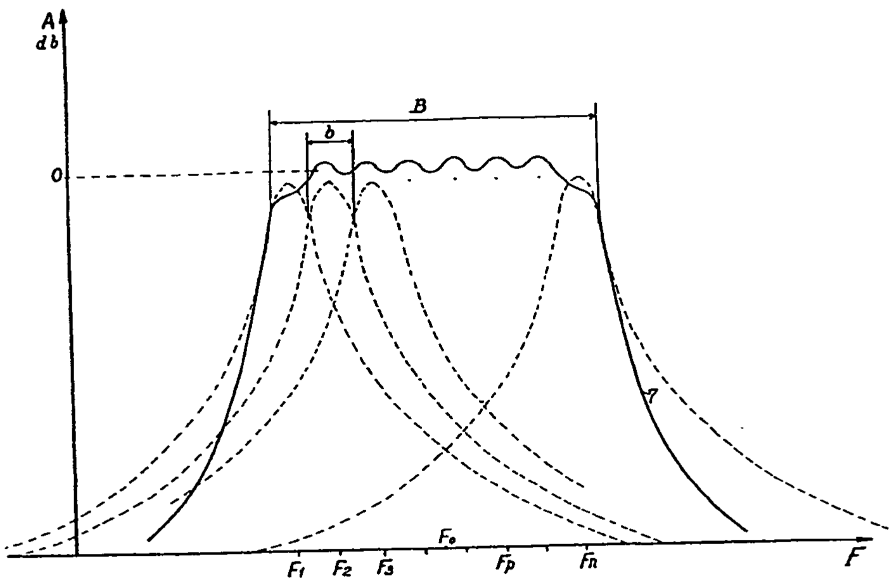

Fig. 2

1,062,269 COMPLETE SPECIFICATION
3 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

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3 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

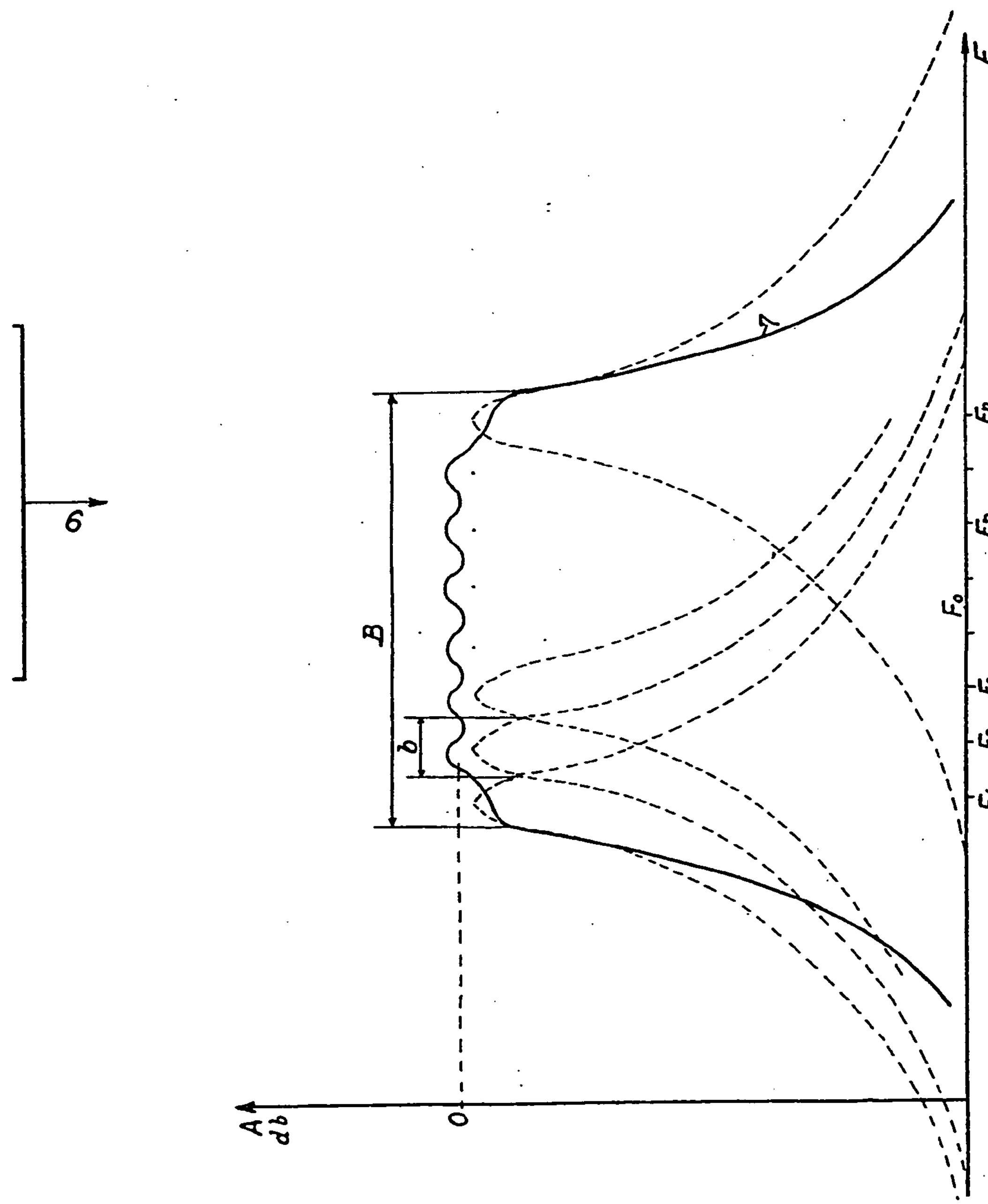

Fig. 2